"On the Relations of the Diurnal Barometric Maxima to certain critical Conditions of Temperature, Cloud, and Rainfall." By HENRY F. BLANFORD, F.R.S. Received March 30,—Read May 3, 1888.

It is not my purpose in this paper to discuss the general problem of the diurnal barometric variation. It is certainly a very complex phenomenon, and one of which no satisfactory analysis has yet been made. The atmospheric stress (whatever be its nature) that originates the oscillation, is followed by movements which alter both the vertical and horizontal distribution of the gravitating mass, and the striking differences that characterise the diurnal curve of pressure on mountain peaks, plains, and valleys, and on the ocean as compared with the land, are doubtless due in a large measure to these resulting redistributions of the mass.

Amid all the recorded variations of the oscillation as a whole, the feature that displays the greatest constancy is the occurrence of a maximum in some hour of the forenoon, and of a second maximum one or two hours before midnight. The exceptional cases, in which these two critical phases are much shifted from their normal positions, are but few, and may probably all be explained by gravitation effects being superadded to the normal semidiurnal oscillation.

One of the most anomalous forms of the diurnal oscillation yet recorded is that given by Professor Mohn, for the North Atlantic, between latitudes 62° and 80°, in the summer months.* The general form of this pressure curve is similar to that of the diurnal temperature curve. It falls to a minimum in the early morning hours, and rises to a maximum between 1 h. and 3 h. 30 m. P.M. But of the three curves for different years and latitudes given by Professor Mohn, two show, as a subordinate feature, a small rise to a secondary maximum, between 10 and 11 P.M., and two an irregularity in the morning rise, such as would result from a small wave with a maximum about 7 or 8 A.M., in combination with the principal oscillation of twenty-four hours' period. At Christiania and Upsala the phases of the single period oscillation are reversed, the maximum being in the night, the minimum in the day, but the semidiurnal element exhibits characters similar to those of the North Atlantic curve.

This comparative constancy of the semidiurnal element of the oscillation, which was originally pointed out by Lamont,† seems to indicate that it depends more directly on the action of the sun than

* 'Norske Nordhavs Expedition,' 1876–1878.

† 'Sitzungsber. d. Bayerisch. Akademie,' 1862, vol. 1, p. 89.

does the diurnal element, and that its explanation is a first necessary step to that of the whole phenomenon. The object of the present paper is to draw attention to the approximate coincidence of its maximum phases with certain critical phases of temperature, cloud, and rainfall, which may at least help to throw some light on its physical causes.

Forenoon Maximum.

It was noticed independently by Espy, in 1840,* Davies, in 1859,† and Kreil, in 1861,‡ that the forenoon maximum of the barometric oscillation approximately coincides with the most rapid rise of temperature, and each of these writers attributed the rise of pressure to the reactionary effect of the heated and expanding atmosphere. The only data, however, given by any of them in support of the statement are the horary variations of the temperature and pressure at Prague, by Kreil, and a rough diagram of the diurnal curves at Padua, by Davies; and shortly after the publication of Kreil's paper, the subject was very fully discussed by Lamont, in the paper already referred to in the 'Sitzungsberichte' of the Bavarian Academy, wherein he showed that, on the ordinary assumption that the atmosphere is free to expand in a vertical direction, against no other resistance than the static pressure of the superincumbent mass, the supposed reactionary effect would be inappreciable.

Since the publication of Lamont's paper, I am not aware that any physicist has paid further attention to the hypothesis in question, or thought it worth while to appeal to further evidence in verification of the observation on which it is based, until quite recently. But in 1876, in noticing the subject of the barometric oscillation in the 'Indian Meteorologist's Vade Mecum,' it occurred to me that Lamont's assumption that the atmosphere is free to expand vertically, lifting the superincumbent mass, is subject to an important modification which may greatly alter the conditions of the problem as contemplated by him.

These conditions take no account of the resistance to expansion that must be opposed by the highly attenuated but extremely cold external atmospheric strata of great but unknown thickness, the existence of which is proved by the phenomena of luminous meteors.

If a sheet of the atmospheric envelope, of indefinite horizontal extent, resting on the earth's surface, be heated and charged with vapour, the first effect will be an increase of its elastic tension, which will be relieved by a wave of elastic compression transmitted to the

* 'Brit. Assoc. Rep.,' 1840, Part II, p. 55.
† 'Edinburgh Phil. Journ.,' vol. 10, 1859, p. 225.
‡ 'Wien. Akad. Sitzungsber.,' vol. 43 (Abth. 2), p. 121.

overlying strata. Having regard to the slow rate at which this wave is generated, the rise of temperature, even in such a climate as that of Northern India, not exceeding 5° or 6° in the hour of most rapid heating, equivalent to an increment of less than $\frac{1}{100}$th of the initial pressure, it appears to me that the rate of propagation will be sensibly that due to half the height of a homogeneous atmosphere, or a little more than two-thirds the rate of the sound-wave. This rate will be continually retarded as the wave advances through the loftier and colder strata, being proportional to the square root of the absolute temperature of each stratum. And it will depend on the thickness of the atmospheric sheet heated, the amount of the heating, and on the thickness and temperature of the cold external strata, whether the retardation may not be such as to allow of the tension of the lower strata becoming such as is indicated by the barometer at the time of the forenoon maximum. Under such circumstances, the instant of maximum pressure should coincide with that of the most rapid rise of temperature and vaporisation.

I do not think that our knowledge of any of these fundamental conditions is such as to justify a rejection of the hypothesis on *à priori* grounds, and it may therefore be worthy of inquiry how far it is in accordance with verifiable observation. At Calcutta, the atmospheric pressure at 9 h. 30 m. A.M. is about $\frac{1}{300}$th greater than at the time of the morning minimum; an increase which would be produced by heating the air in a closed vessel less than 2°. A retardation of about half an hour in the dissipation of the increased pressure produced by heating and evaporation would suffice to produce the observed effect.

Dr. Sprung, in his admirable manual, the 'Lehrbuch der Meteorologie,' published in 1885, has referred to the above hypothesis,* and has tested the coincidence of the critical phases of temperature and pressure by the summer results of the hourly observations and autographic registers of the Prague Observatory, from 1842 to 1861, which have been recomputed by Professor Augustin. The result of this test appears to be satisfactory. At Prague, on the mean of the summer months, the forenoon barometric maximum occurs a little after 8 A.M., and nearly coincides with the most rapid rise of temperature.†

In India there is no station at which the forenoon maximum falls at so early an hour at any season; but at Yarkand and Kashghar, according to Dr. Scully's valuable observations, in the summer, it occurs even earlier than at Prague, while in the winter it is as late as the mean epoch at Calcutta. It is true we have only fifteen series of

* *Op. cit.*, p. 336.

† As computed from the figures given by Dr. Sprung, by the application of the method of differences (see footnote below), the barometric maximum occurs nineteen minutes later than the instant of most rapid heating.

hourly readings for the winter months, November to February, taken at intervals of seven or eight days, and but eight series for June and July, but so regular is the march of the diurnal variation both of temperature and pressure in this climate, that even these suffice to show the distinctive characters of the curves at both seasons. The observations have been published at length in the first volume of the 'Indian Meteorological Memoirs.'* To eliminate small irregularities, corrected hourly values have been computed from these by means of the harmonic formula. A very exact determination of the critical phases cannot of course be expected from such data, but according to the method of computation adopted,† the epochs of the forenoon pressure maximum and of most rapid heating are as follow at the two seasons :—

	Max. rise temp.	Bar. max.
Winter months....	9 h. 38 m. A.M.	9 h. 36 m. A.M.
Summer months ..	7 h. 56 m. „	7 h. 38 m. „

* *Op. et vol. cit.*, p. 94, *et seq.*

† Throughout this paper the time of most rapid heating has been determined in the following manner : in general, from the uncorrected means of the observations, which, for the reasons shown by Dr. Bergsma ('Batavia Mag. and Met. Obs.,' vol. 1, p. xvii) and in accordance with my own experience and that of other Indian meteorologists, if the observations are sufficiently extensive, are more trustworthy than the so-called corrected values obtained by computing them from three or four terms of the harmonic formula.

The instant of most rapid rise of temperature may be ascertained by twice differentiating for the values of t the formula which expresses the temperature θ as a function of the time t, and putting

$$\frac{d^2\theta}{dt^2} = 0.$$

The most convenient formula for this purpose is that of the method of differences employed by Dr. Jelinek for obtaining the approximate times of the maximum and minimum phases of temperature, pressure, &c. On taking the first, second, and third differences of the temperatures at the clock hours, two before and two after the instant of most rapid rise, the hour in which this occurs is shown by the change of algebraical sign of the second order of differences. Denoting that which precedes this change by Δ_2, and the differences of the first and third order next following in order of sequence by Δ' and Δ'_3, the second differentiation of the formula

$$\theta = a + t\Delta'_1 + \frac{t\,(t-1)}{2}\,\Delta_2 + \frac{(t+1)\,t\,(t-1)}{6}\,\Delta'_3 + \ldots .$$

neglecting the higher terms, gives

$$\frac{d^2\theta}{dt^2} = \Delta_2 + t\Delta'_3 = 0,$$

whence

$$t = -\frac{\Delta_2}{\Delta'_3},$$

which value of t reckons from the clock hour corresponding to Δ_2. The epoch thus obtained has an error of a few minutes only, and is quite accurate enough for the present purpose.

Considering the character of the data and the method of computation, this close coincidence in the winter months must be regarded as in some degree fortuitous.

In order to test the hypothesis more thoroughly, I have selected four stations, the data for which are more ample, and thoroughly trustworthy, viz., Bombay, Calcutta, Batavia, and Melbourne; and in the case of the last three, I have compared the critical phases in question for every month of the year.

The data for Bombay are taken from Mr. C. Chambers's volume on the Meteorology of the Bombay Presidency. The barometric data for Calcutta are extracted from vol. 1 of the 'Indian Meteorological Memoirs,' and as I have not the corresponding thermometrical data at hand,* I have substituted those obtained from the measurements of the Alipore photographic traces for the six years 1881–1885. These latter relate, therefore, to a different and later series of years, and are furnished by a different observatory, but this is hardly a matter of importance. The Batavian data are taken from the first volume of Dr. Bergsma's 'Magnetical and Meteorological Observations,' and have been derived from the hourly readings of three years; and the Melbourne data are from Dr. Neumayer's discussion of the observations of the Flagstaff Observatory. They extend over five years. The results are shown in the following table:—

Bombay.

	Max. rise temp.	Bar. max.	Interval.
April to September, mean	7 h. 45 m. A.M.	9 h. 43 m. A.M.	1 h. 58 m.
October to March ,,	7 h. 53 m. ,,	9 h. 31 m. ,,	1 h. 38 m.

* Since the reading of the paper before the Society I have received from Calcutta the mean values of the horary readings of the thermometer, corresponding to those of the barometer here dealt with. See appended note at the end of the paper.

	Calcutta.			Batavia.			Melbourne.		
	Max. rise temp.	Bar. max.	Interval.	Max. rise temp.	Bar. max.	Interval.	Max. rise temp.	Bar. max.	Interval.
January...........	8 h. 41 m.	9 h. 44 m.	1 h. 3 m.	8 h. 36 m.	9 h. 22 m.	0 h. 46 m.	7 h. 7 m.	8 h. 33 m.	1 h. 26 m.
February..........	8 36	9 52	1 16	8 34	9 26	0 52	7 50	9 5	1 15
March.............	8 16	9 47	1 31	8 33	9 15	0 42	8 24	9 2	0 38
April.............	8 10	9 35	1 25	8 36	9 13	0 37	8 43	9 25	0 42
May...............	7 11	9 23	2 12	8 38	9 8	0 30	9 5	9 18	0 13
June..............	6 52	9 22	2 30	8 34	9 4	0 30	9 59	9 29	−0 30*
July..............	8 15	9 33	1 18	8 46	9 11	0 25	9 31	9 30	−0 1
August............	8 28	9 38	1 10	8 44	9 2	0 18	8 51	9 20	0 29
September.........	7 40	9 33	1 53	8 22	8 54	0 32	7 58	8 52	0 54
October...........	8 2	9 25	1 23	7 56	8 59	1 3	6 56	8 51	1 55
November..........	8 23	9 24	1 1	8 1	8 58	0 57	6 42	8 27	1 45
December..........	8 36	9 34	0 58	8 33	9 14	0 41	6 49	8 34	1 55
Year..........	8 27	9 35	1 8	8 33	9 8	0 35	8 36	9 7	0 31

* The minus sign indicates that the maximum of pressure precedes that of the temperature rise.

From this table it appears that only in one or two of the winter months at Batavia and Melbourne does the forenoon maximum of pressure coincide so nearly with the moment of most rapid heating as at Prague and Yarkand. In all cases, except in the midwinter months at Melbourne, the former follows the latter by an interval which averages 31 minutes at Melbourne, 35 minutes at Batavia, 1 hour and 8 minutes at Calcutta, and 1 hour and 48 minutes at Bombay. But it is to be noticed that, at all the stations, this interval is shortest in the winter and greatest in the summer. It is true that the computed temperature epochs may be 10 minutes or so in error, owing to the merely approximative character of the method adopted, and that, for an hour or more afterwards, the change in the rate of rise is very small, not exceeding a few tenths of a degree per hour; but the retardation of the barometric maximum is too systematic to be explained away by any such considerations. There are, however, others of a very obvious character.

The hypothesis attributes the increase of pressure in the forenoon to the mean increase of tension in the atmosphere up to a very great height, not to that of the lowest stratum only. And since this latter is heated much more rapidly than the higher strata, and that, owing to variations in the character of the earth's surface, the rates of heating in contiguous areas of the lower strata themselves vary indefinitely, the convective movements, which are set up in consequence, produce innumerable small modifications in the form of the local temperature curves, which will to a great extent eliminate each other when a mean is taken of those of higher and lower strata; and the general form of this curve for the greater mass of the superincumbent atmosphere must be much more constant than that deduced from the thermometer readings of our observatories. Generally, as was assumed by Lamont in his discussion of the problem, the critical phases of the former will be later than those of the latter. This retardation will be greatest where the diurnal range of temperature is greatest, and especially at such intertropical stations as Bombay and Calcutta.

The diurnal march of the temperature at such an observatory as the Colába Observatory at Bombay, must be influenced in a high degree by the local influx of cooler air from the neighbourhood. Situated on a narrow point of land, and surrounded, in all directions but one, by many miles of sea, the atmosphere is scarcely ever calm, and a wind from any quarter other than between north and north-west comes directly from the sea close at hand, the movement of the air increasing with the rise of temperature. To this circumstance, in all probability, it is due that this rise undergoes a slight check at an earlier hour than at any of the other stations. It is very slight, as is shown in the following table, which gives the amount of the rise for

each hour from 6 A.M. to noon in each half of the year. But it is sufficient to explain the early occurrence of its maximum.

Hourly Change of the Forenoon Temperature at Bombay.

Hour..............	6 to 7	7 to 8	8 to 9
April to September..	+0·9	+1·2	+1·1 deg. Fahr.
October to March ..	+0·5	+2·1	+1·9 „ „
Hour..............	9 to 10	10 to 11	11 to noon
April to September..	+0·9	+0·8	+0·7 deg. Fahr.
October to March ..	+1·8	+1·7	+1·7 „ „

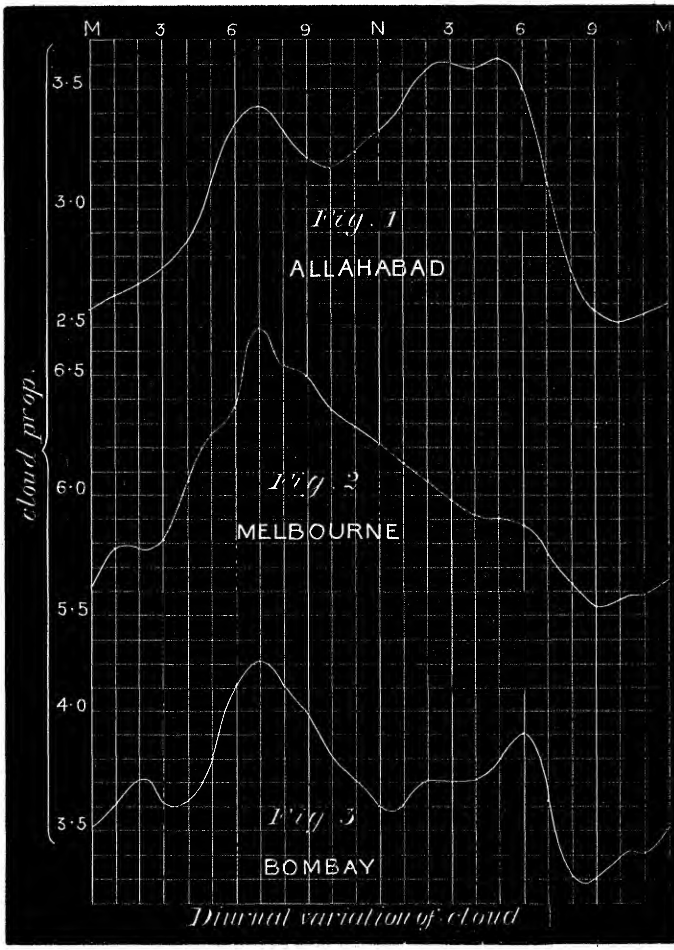
At Calcutta, Batavia, and Melbourne, the observatories are sufficiently far from the sea to exclude the supposition that they are subject to its influence in anything like the same degree as Bombay, but at all of these the temperature must be influenced by convection, which is most active in the summer months; and, as already remarked, it is at this season that the instant of most rapid heating precedes the barometric maximum by the longest interval. In certain of the winter months, viz., August at Batavia, and May and July at Melbourne, the time of most rapid heating, and that of the barometric maximum are as nearly coincident as at Prague and Yarkand; and in June, at Melbourne, the latter appears to anticipate the former by about half an hour. Of this opposite anomaly I am not prepared with any explanation. More than one circumstance might be imagined in the local conditions of the observatory which would retard the instant of greatest rise, but without searching inquiry and examination on the spot, any suggestion would be mere vain surmise. I may, however, notice that the June curve of temperature departs from the ordinary parabolic form in a manner that points to the existence of some local irregularity, and that similar irregularities are noticeable in other parts of some others of the monthly curves.

As a final conclusion, if these data, when subjected to the rigorous test I have applied, do not give strong support to the hypothesis, neither do they, with the single exception just mentioned, show any discrepancy which is not susceptible of a simple and probable explanation; and the single exception is one which might also probably be explained, were the requisite information available.

Evening Maximum.

The tendency of the skies to clear after sunset in settled weather has been noticed by many writers, even in the irregularly variable climates of Europe, and in India it is most striking at all seasons of the year. The cloud registers of nearly all stations at which hourly observations have been made, show a strongly marked minimum

between sunset and midnight, the average hour being about 10 P.M.; and some show a second subordinate minimum about 9 or 10 A.M. The cloud curves for Allahabad given by Mr. S. A. Hill on Plate 28, vol. 1 of the 'Indian Meteorological Memoirs,' exhibit both these minima in most months of the year, that of the evening being the absolute minimum of the twenty-four hours. On the average of the year, the mean proportion, at 10 P.M., is 2·52 (on the 0 to 10 scale), that of the twenty-four hours being 3·10: the deficiency therefore is more than one-sixth. The cloud curves of Melbourne given by Dr. Neumayer also show that, in every month except November, the diurnal minimum of cloud is between 7 h. 30 m. P.M. and 1 h. 30 m. A.M.; and, on the mean of the whole year, it occurs at 9 h. 44 m. P.M. At this hour, the mean proportion is 5·55, the general mean of the twenty-four hours being 6·56; so that, here also, the deficiency amounts to one-sixth of the average. At Bombay, the absolute minimum, according to Mr. Chambers's table, occurs at 8 and 9 P.M., and the deficiency is one-ninth of the general average. The mean diurnal cloud curves of Allahabad, Melbourne, and Bombay, for the average of the whole year are given in figs. 1, 2, and 3.



More striking than any of these is the concurrent evidence afforded by the diurnal variation of the Calcutta rainfall. Two series of data have been published; the one based on hourly observations of the occurrence of rain during twenty-one years,* the other giving the results of seven years' records of a self-registering rain-gauge,† which affords measurements of the quantities that fell in each hour as well as an enumeration of rainy hours. The two series are generally accordant, and exhibit a diurnal fluctuation of a remarkably pronounced character. This differs at different seasons of the year, as might indeed be anticipated, and it is in the rainy season, when the air is

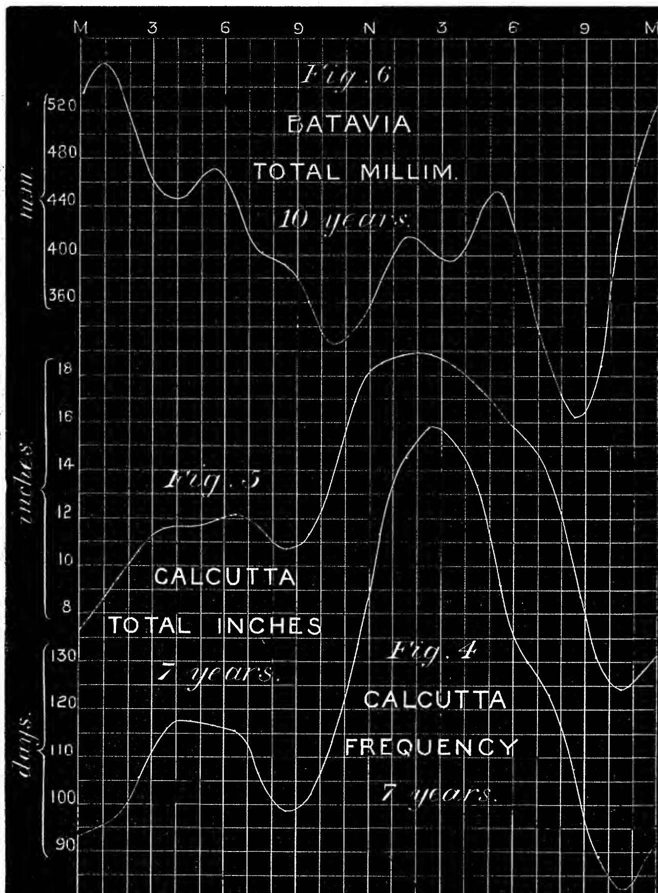
* 'Asiat. Soc. Bengal Journ.,' vol. 48, 1879, Part II, p. 41.

† 'Indian Meteor. Mem.,' vol. 4, p. 43.

nearest to saturation, that the forenoon and late evening minima are most strongly developed. The numerical results of this season, afforded by both series, and also those of the whole year, are given in the following table, and, in parallel columns, smoothed values obtained by the formula

$$b' = \frac{a + 2b + c}{4},$$

where a, b, and c are the observed values for any three consecutive hours, and b' the smoothed value of the middle term. The curves afforded by the latter for the seven-year series are represented by figs. 4 and 5.



Diurnal variation of rainfall.

Diurnal Variation of Rainfall Frequency and Quantity at Calcutta.

Hours.	In seven years (Alipore).								In twenty-one years (Chowringhee). Frequency.	
	Quantities (inches).				Frequency (hours × 3).					
	June to October.		Year.		June to October.		Year.		June to Oct.	Year.
	Obs.	Comp.	Obs.	Comp.	Obs.	Comp.	Obs.	Comp.	Obs.	Obs.
Mid. to 1....	8·52	7·89	9·51	9·26	100	94	117	116	298	343
1 „ 2....	8·28	9·24	8·77	10·29	89	96	105	113	327	374
2 „ 3....	11·30	10·63	12·97	11·72	106	105	124	121	348	409
3 „ 4....	12·35	11·49	13·27	12·54	118	115	132	130	353	410
4 „ 5....	11·21	11·64	12·00	12·54	119	117	133	130	364	414
5 „ 6....	11·36	11·82	12·38	12·57	114	116	125	128	376	426
6 „ 7....	12·85	12·12	13·08	12·84	119	115	129	126	373	430
7 „ 8....	12·42	11·73	13·45	12·61	108	106	121	117	373	426
8 „ 9....	10·47	10·81	11·64	11·88	91	98	101	109	357	409
9 „ 10....	8·46	11·19	9·82	12·18	104	102	116	112	410	461
10 „ 11....	13·80	13·82	14·04	14·65	109	114	117	124	458	522
11 „ noon..	18·87	16·88	19·86	17·84	133	134	143	144	505	565
Noon „ 13....	18·50	18·50	19·74	19·91	160	156	172	169	543	603
13 „ 14....	19·13	18·94	21·36	20·82	172	172	190	189	537	600
14 „ 15....	19·10	18·94	21·11	21·20	184	178	203	198	572	646
15 „ 16....	18·97	18·54	21·75	21·58	171	176	192	198	477	571
16 „ 17....	17·62	17·60	21·44	21·94	178	167	204	194	464	566
17 „ 18....	16·86	16·38	23·21	22·40	141	146	174	181	413	544
18 „ 19....	13·47	15·38	21·43	22·74	126	130	173	176	397	521
19 „ 20....	17·52	13·85	25·85	21·49	129	123	185	177	343	495
20 „ 21....	10·13	10·63	17·67	17·25	107	107	163	160	321	449
21 „ 22....	5·24	7·12	9·25	12·05	86	89	130	134	261	361
22 „ 23....	4·76	5·88	8·31	9·25	78	82	111	116	282	360
23 „ mid...	6·48	6·53	8·67	8·77	87	88	114	114	263	319

In the rainy season there were 2929 rainy hours in the seven years, giving an average of 122 for each hour of the day. But for the hour between 10 and 11 P.M. there were but 78 instances of rain, or but two-thirds of this average, and from 8 to 9 A.M. but 91 instances of rain, or three-fourths of the average. The deficiency in the quantity of the rainfall was even more striking. The average per hour of the day was 12·81 inches, but the recorded amount for the hour between 10 and 11 P.M. was only 4·76 inches, or less than two-fifths of the general average, and that from 9 to 10 A.M. was 8·46 inches, or little more than two-thirds.

Another equally striking example of the approximate coincidence of interruptions of the rainfall, about the time of the diurnal maxima of pressure, is afforded by Batavia, on the evidence of ten years' registers of the hourly rainfall, published by Dr. Bergsma in the 3rd volume of the 'Batavia Observations.' Here also, it is only the rainy reason (December to January) that exhibits this feature in a very decisive manner, and the coincidence is the more remarkable, since, in another respect, the diurnal variation of the rainfall of Batavia stands in marked contrast to that of Calcutta. At Calcutta the greater proportion of the rain falls in the daytime; at Batavia at night. The percentages were respectively as follows :—

	Calcutta.	Batavia.
From 6 A.M to 6 P.M.	60·3 per cent.	47·8 per cent.
From 6 P.M. to 6 A.M.	39·7 ,,	52·2 ,,

And the Batavian maximum follows the minimum within four hours, in the proportion of 5 to 2. The following table gives the total rainfall in millimetres, recorded at each hour of the day of the three rainy months during the ten years 1866–1875 (Sunday excepted), and in a parallel column the smoothed values computed as in the former case. The curve, fig. 6, is drawn from these latter figures.

Total Hourly Rainfall at Batavia (December to February), ten years.

Hours.	Observed.	Computed.	Hours.	Observed.	Computed.
	mm.	mm.		mm.	mm.
Midn. to 1...	571	550	Noon to 13...	364	374
1 ,, 2...	584	547	13 ,, 14...	423	413
2 ,, 3...	448	489	14 ,, 15...	413	403
3 ,, 4...	478	451	15 ,, 16...	362	394
4 ,, 5...	401	452	16 ,, 17...	439	432
5 ,, 6...	527	472	17 ,, 18...	486	446
6 ,, 7...	435	445	18 ,, 19...	373	385
7 ,, 8...	382	401	19 ,, 20...	307	312
8 ,, 9...	404	392	20 ,, 21...	263	266
9 ,, 10...	379	362	21 ,, 22...	231	308
10 ,, 11...	288	326	22 ,, 23...	508	431
11 ,, noon.	351	338	23 ,, midn.	475	507

The general average of all the hours is 412 mm. per hour, but the quantity recorded between 9 and 10 P.M. is only 231 mm., or little more than half, and that between 10 and 11 A.M. 288 mm., or little more than three-fifths of this average. It is to be observed that the forenoon minimum of Batavia falls an hour later than that of Calcutta, whereas the evening and principal minimum is an hour earlier. This is exactly what might be expected from the combination of a double diurnal oscillation with one of single period, the latter having its maximum in the former case at night, in the latter in the daytime.

The Melbourne hourly rainfall tables show great variations in different months, and admit of very little definite conclusion, except that, as at Batavia, there is more rain at night than in the day. It is then only in the warm and nearly saturated atmosphere of Bengal and Java, in their respective rainy seasons, that these diurnal interruptions of the rainfall about the hours of the two barometric maxima are decidedly manifested. But in these two cases they are most marked; and this circumstance, taken in conjunction with the corresponding cloud variation, which is shown by so many stations, points strongly to a causal connexion between the diurnal variation of pressure and the condensation of atmospheric vapour in the cloud-forming strata of the atmosphere, which, I think, we can scarcely fail to recognise.

The mere fact that an increase of atmospheric pressure, from whatever cause arising, is accompanied with a dissipation of cloud and a diminution of rainfall, would not perhaps call for special remark. But it is to be observed that whereas the nocturnal barometric maximum, at all the stations here dealt with, is less pronounced than that of the forenoon, the concomitant effects in the clearing of the atmosphere and in the check in the rainfall are much greater in the former case than in the latter. They seem to point to a forcible compression of the atmosphere, and dynamic heating of the cloud-forming strata. And some such temporary effect does not seem impossible, even at a time when the earth's surface and the air immediately in contact with it are cooling rapidly. Moreover the temperature curves of Prague, Calcutta, and Batavia all show a very slight irregularity about 10 P.M., which indicates a slight check in the fall of temperature about that hour greater than takes place either in the preceding or subsequent hour, and which may possibly be the manifestation of such an action in the lowest atmospheric stratum. Slight as it is, the fact that it occurs at the same hour in all these curves, and that it coincides with the evening pressure maximum and the strongly marked minima of cloud and rainfall, is at least significant.

When we tabulate the differences of the first and second orders of the hourly means of the original observations, at the three stations

specified, it is found that the second difference corresponding to 10 P.M., with a positive sign, has a greater numerical value than either of those preceding and following it, instead of an intermediate value, as would be the case if the fall of temperature after sundown were decreasing uniformly. In the following tables, the figures for Prague and Batavia represent hundredths of a centigrade degree, those for Calcutta hundredths of a Fahrenheit degree. The figures for Calcutta are derived from only six years' autographic traces; those for Prague, apparently from eighteen or twenty years' observations and traces; and those for Batavia from ten years' readings of a standard thermometer. No correction has been applied to the means of the observations as recorded.

Prague (summer).

Hours, P.M.	7 to 8	to 9	to 10	to 11	to mid.
Δ_1 Change of temperature	−115	−94	−85	−53	−44
Δ_2 Change of rate of fall	+21	+ 9	+32	+9	

Calcutta (year).

Hours, P.M.	5 to 6	to 7	to 8	to 9	to 10	to 11	to mid.
Δ_1 Change of temperature	−145	−248	−215	−111	−87	−61	−54
Δ_2 Change of rate of fall	−103	+33	+104	+24	+26	+7	

Batavia (year).

Hours, P.M.	5 to 6	to 7	to 8	to 9	to 10	to 11	to mid.
Δ_1 Change of temperature	−79	−76	−55	−41	−36	−27	−27
Δ_2 Change of rate of fall	+3	+21	+14	+5	+9	0	

The only further point of some significance, to which I have to draw attention, is that the hour of the evening barometric maximum about coincides with the time when the temperature curve ceases to be strongly concave, and becomes nearly rectilinear, indicating a nearly uniform rate of cooling from that time up to just before sunrise. This fact suggests the possibility that the evening maximum of pressure may be determined by the check in the descent of the cooling and collapsing atmosphere which takes place from 6 or 7 P.M. to about 10 P.M.* But it is very probably combined with other elements,

* This explanation was suggested by Kreil and Espy, and also by myself in a paper read before the Asiatic Society of Bengal in 1876. On it Dr. Sprung remarks:—" Es bleibt aber gänzlich unverständlich, weshalb dieser Effect, schon um 10 Uhr abends, und nicht zur Zeit des Temperatur-Minimums gegen 6 Uhr

among which may be the return of the morning wave of pressure. And indeed unless there be such repetition, it is difficult to understand why the rise of pressure sets in so early as between 4 and 5 in the afternoon, instead of between 6 and 7 P.M.; that is, after the time when the fall is most rapid. And unless the evening wave is repeated in like manner, to explain why the morning rise of pressure begins at least two hours before sunrise.

Note added August 15, 1888.

Since the foregoing paper was read before the Society, I have received a table of the mean horary readings of the thermometer, recorded at the Surveyor-General's office, Calcutta, (formerly the Calcutta Observatory) during the same years that have furnished the barometric data, quoted in the text, page 415. They have been computed to hundredths of a Fahrenheit degree, and are as follow—(p. 426).

The instant of the most rapid rise of forenoon temperature computed from these figures by the method described in the footnote on page 413 is as follows in each month :—

	Max. rise temp.		Max. bar.		Interval.	
January	8 h.	53 m.	9 h.	44 m.	0 h.	51 m.
February....	8	46	9	52	1	8
March	8	46	9	47	1	1
April	8	22	9	35	1	13
May	7	54	9	23	1	29
June........	8	2	9	22	1	20
July	7	55	9	33	1	38
August	8	24	9	38	1	14
September ..	7	41	9	33	1	52
October	7	44	9	25	1	41
November ..	7	56	9	24	1	28
December ..	8	56	9	34	0	40
Year....	8	27	9	35	1	8

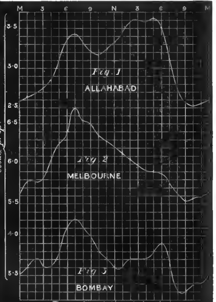
The variations from month to month shown by this table are, as might be expected, less than in the table at page 415 computed from six years only, but the mean interval for the whole year is exactly the same.

The irregularity of the evening fall of temperature noticed at page 423 does not appear in the results of this table, and it must therefore remain doubtful whether its occurrence in the three registers quoted in the text is more than a fortuitous coincidence.

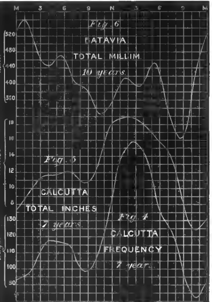
morgens eintreten soll." This objection would be quite valid were the cooling of the atmosphere proceeding at an uniform rate, but not, I think, to the actual facts of the case as above set forth. This was not noticed in my former communication, to which Dr. Sprung refers.

Mean Values of the Hourly Readings of the Thermometer at Calcutta from 1853 to 1877, recorded daily, Sundays and Public Holidays excepted (deg. F.).

Hours.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
24......	64·13	68·97	76·02	80·12	81·61	82·43	81·75	81·49	81·56	79·25	71·80	64·44
1......	63·44	68·30	75·44	79·72	81·31	82·18	81·49	81·24	81·29	78·90	71·25	63·77
2......	62·79	67·70	74·96	79·31	81·04	81·93	81·24	81·05	81·05	78·55	70·74	63·16
3	62·21	67·18	74·45	78·97	80·80	81·70	81·00	80·80	80·85	78·27	70·20	62·55
4......	61·59	66·62	73·95	78·60	80·60	81·52	80·80	80·57	80·63	77·91	69·65	61·96
5	61·09	66·06	73·56	78·29	80·35	81·40	80·64	80·44	80·48	77·75	69·24	61·49
6......	60·65	65·60	73·14	78·14	80·49	81·53	80·68	80·40	80·38	77·52	68·84	60·96
7......	60·34	65·42	73·41	79·03	81·73	82·42	81·37	80·98	81·04	78·30	69·14	63·85
8......	62·45	67·77	76·14	81·81	84·40	84·10	82·73	82·22	82·69	80·57	72·13	63·63
9	65·96	71·21	79·21	84·84	86·92	85·79	84·03	83·58	84·04	82·29	74·92	66·86
10......	69·27	74·32	82·17	87·45	89·23	87·22	85·15	84·75	85·19	83·72	77·30	70·06
11......	72·13	77·06	84·90	89·92	91·04	88·29	86·03	85·67	86·09	84·96	79·35	72·86
12......	74·35	79·32	87·03	91·53	92·34	88·96	86·59	86·18	86·74	85·77	80·76	74·89
13......	75·84	80·91	88·55	92·73	93·26	89·34	86·91	86·45	86·96	86·22	81·66	76·20
14......	76·81	81·91	89·46	93·38	93·65	89·38	86·75	86·41	86·85	86·38	82·19	77·03
15......	77·15	82·40	89·86	93·38	93·48	89·13	86·40	86·14	86·35	86·30	82·00	76·86
16......	75·72	81·84	89·48	92·48	92·53	88·52	85·98	85·77	85·83	85·59	80·60	75·33
17......	74·17	80·55	87·88	90·50	90·81	87·61	85·38	85·01	84·92	84·61	79·13	73·64
18......	71·56	77·60	84·84	87·68	88·31	86·30	84·47	83·97	83·82	82·83	77·04	71·11
19	69·57	75·07	82·06	85·17	85·77	84·94	83·50	83·13	83·12	81·72	75·60	69·29
20	68·09	73·33	80·18	83·28	84·21	84·08	82·97	82·66	82·66	80·98	74·55	67·97
21......	66·90	71·98	78·72	82·12	83·15	83·45	82·60	82·36	82·30	80·40	73·63	66·85
22......	65·89	70·86	77·68	81·26	82·55	82·98	82·29	82·03	82·00	79·89	72·87	65·90
23......	65·08	70·03	76·85	80·63	81·99	82·66	81·98	81·80	81·70	79·46	72·20	65·11



Diurnal variation of cloud



Diurnal variation of rainfall.